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MINISTRY USE ONLY

BRITISH COLUMBIA

Chemistry 12

AUGUST 2003

Course Code = CH

Student Instructions

1. Place the stickers with your Personal Education Number (PEN) in the allotted spaces above. **Under no circumstance is your name or identification, other than your Personal Education Number, to appear on this booklet.**
2. Ensure that in addition to this examination booklet, you have a **Data Booklet** and an **Examination Response Form**. Follow the directions on the front of the Response Form.
3. **Disqualification** from the examination will result if you bring books, paper, notes or unauthorized electronic devices into the examination room.
4. When instructed to open this booklet, **check the numbering of the pages** to ensure that they are numbered in sequence from page one to the last page, which is identified by

   END OF EXAMINATION.
5. At the end of the examination, place your Response Form inside the front cover of this booklet and return the booklet and your Response Form to the supervisor.

Question 1:

1. . (3)

Question 8:

8. . (2)

Question 2:

2. . (2)

Question 9:

9. . (5)

Question 3:

3. . (3)

Question 10:

10. . (3)

Question 4:

4. . (3)

Question 11:

11. . (3)

Question 5:

5. . (6)

Question 12:

12. . (1)

Question 6:

6. . (2)

Question 13:

13. . (5)

Question 7:

7. . (2)

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GENERAL INSTRUCTIONS

1. Aside from an approved calculator, electronic devices, including dictionaries and pagers, are **not** permitted in the examination room.

2. All multiple-choice answers must be entered on the Response Form using an **HB pencil**. Multiple-choice answers entered in this examination booklet will **not** be marked.

3. For each of the written-response questions, write your answer in the space provided in this booklet.

4. Ensure that you use language and content appropriate to the purpose and audience of this examination. Failure to comply may result in your paper being awarded a zero.

5. This examination is designed to be completed in **two hours**. *Students may, however, take up to 30 minutes of additional time to finish*.

CHEMISTRY 12 PROVINCIAL EXAMINATION

1. This examination consists of **two** parts:

	Value	Suggested Time
PART A: 48 multiple-choice questions	60	70
PART B: 13 written-response questions	40	50
Total:	**100 marks**	**120 minutes**

2. The following tables can be found in the separate **Data Booklet**:
   - Periodic Table of the Elements
   - Atomic Masses of the Elements
   - Names, Formulae, and Charges of Some Common Ions
   - Solubility of Common Compounds in Water
   - Solubility Product Constants at 25°C
   - Relative Strengths of Brønsted-Lowry Acids and Bases
   - Acid-Base Indicators
   - Standard Reduction Potentials of Half-cells

   No other reference materials or tables are allowed.

3. **A calculator is essential for the Chemistry 12 Provincial Examination.** The calculator must be a hand-held device designed primarily for mathematical computations involving logarithmic and trigonometric functions. The calculator **must not** be programmable. Computers, calculators with a QWERTY keyboard or symbolic manipulation abilities, and electronic writing pads will not be allowed. Students must not bring any external devices (peripherals) to support calculators such as manuals, printed or electronic cards, printers, memory expansion chips or cards, CD-ROMS, libraries or external keyboards. Calculators may not be shared and must not have the ability to either transmit or receive electronic signals. In addition to an approved calculator, students will be allowed to use rulers, compasses, and protractors during the examination.

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PART A: MULTIPLE CHOICE

Value: 60 marks **Suggested Time: 70 minutes**

INSTRUCTIONS: For each question, select the **best** answer and record your choice on the Response Form provided. Using an HB pencil, completely fill in the circle that has the letter corresponding to your answer.

Note that some multiple-choice questions are worth 2 marks.

1. Which of the following reactions would be slowest at room temperature? **(1 mark)**

   A. $Zn_{(s)} + S_{(s)} \rightarrow ZnS_{(s)}$

   B. $Cu_{(s)} + 2AgNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$

   C. $Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow PbI_{2(s)} + 2KNO_{3(aq)}$

   D. $HC_2H_3O_{2(aq)} + KOH_{(aq)} \rightarrow KC_2H_3O_{2(aq)} + H_2O_{(\ell)}$

2. Consider the following reaction:

$$\underset{\text{(yellow)}}{2BaCrO_{4(s)}} + 2H^+_{(aq)} \rightarrow 2Ba^{2+}_{(aq)} + H_2O_{(\ell)} + \underset{\text{(orange)}}{Cr_2O_7{}^{2-}_{(aq)}}$$

   The progress of the reaction could be followed by observing the rate of **(1 mark)**

   A. mass loss.
   B. decrease in pH.
   C. precipitate formation.
   D. formation of orange colour in the solution.

3. What happens to the activation energy as the temperature in a reacting system increases? **(1 mark)**

   A. the activation energy increases
   B. the activation energy decreases
   C. the activation energy stays the same
   D. the activation energy is converted to kinetic energy

OVER

4. Consider the following information for a reversible chemical reaction:

1	forward activation energy = 20kJ
2	reverse activation energy = 30kJ

Which of the following describes the reaction type and enthalpy change for the forward reaction? **(2 marks)**

	Reaction Type	ΔH Value
A.	exothermic	−10 kJ
B.	exothermic	+10 kJ
C.	endothermic	−10 kJ
D.	endothermic	+10 kJ

5. Consider the following experimental results:

	Experiment 1	Experiment 2
Reactants	$Fe^{2+}_{(aq)} + MnO_4^-{}_{(aq)}$	$MnO_4^-{}_{(aq)} + H_2C_2O_{4(aq)}$
Temperature	20°C	40°C
Concentration	0.5 M solutions	1.0 M solutions
Rates	Fast	Slow

Which factor would account for the faster reaction rate in Experiment 1? **(2 marks)**

A. temperature
B. surface area
C. nature of reactants
D. solution concentration

6. Consider the reaction:

$$C_5H_{12(g)} + 8O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(g)}$$

Which of the following explains, in terms of collision theory, why this reaction occurs in more than one step? **(1 mark)**

A. a low $C_5H_{12(g)}$ concentration

B. low temperature of reactant mixture

C. low probability of a multi-particle collision

D. particles collide with insufficient kinetic energy

7. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

How will the forward and reverse equilibrium reaction rates change when additional H_2 is added to the system? **(1 mark)**

	Forward Rate	Reverse Rate
A.	increase	increase
B.	increase	decrease
C.	decrease	increase
D.	no change	no change

OVER

8. Consider the following system at equilibrium:

$$H_2O_{(g)} + CO_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)}$$

This equilibrium will shift right as the result of the addition of some extra H_2O.
How will this shift affect the concentrations of the other gases? **(2 marks)**

	$[CO]$	$[CO_2]$	$[H_2]$
A.	increases	decreases	decreases
B.	increases	increases	decreases
C.	decreases	increases	increases
D.	decreases	decreases	increases

9. Consider the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)}$$

Which of the following factors will not alter the position of equilibrium? **(1 mark)**

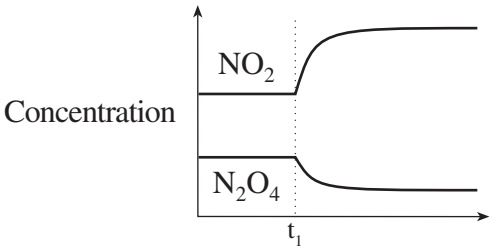
A. a pressure decrease
B. a temperature increase
C. the presence of a catalyst
D. the addition of more $N_{2(g)}$

10. Consider the following equilibrium:

$$N_2O_{4(g)} + \text{energy} \rightleftarrows 2NO_{2(g)}$$

Which of the following graphs shows the result of increasing the temperature at time t_1 ? **(1 mark)**

A.



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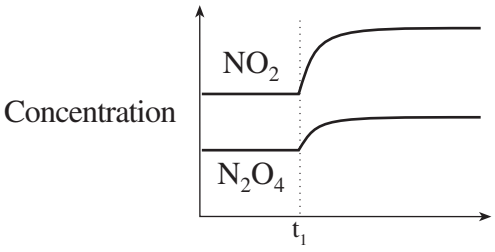
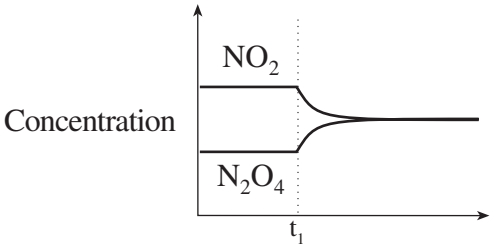
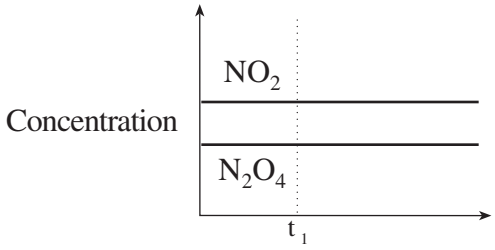


C.



D.



11. Consider the following equilibrium and the table of experimental data:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$$

	Initial		Equilibrium	
	$[N_2O_4]$	$[NO_2]$	$[N_2O_4]$	$[NO_2]$
Trial 1	0.0400	0.0000	0.0337	0.0125
Trial 2	0.0200	0.0600	0.0429	0.0141

Which of the following represents the K_{eq} value? **(1 mark)**

A. 4.64×10^{-3}

B. 3.71×10^{-1}

C. 7.42×10^{-1}

D. 2.16×10^{2}

OVER

12. Which of the following is **least** likely to favour the formation of products? **(1 mark)**

A. $2H_2O_{(g)} \rightleftarrows 2H_{2(g)} + O_{2(g)}$ $K_{eq} = 7.3 \times 10^{-18}$

B. $N_2O_{(g)} + NO_{2(g)} \rightleftarrows 3NO_{(g)}$ $K_{eq} = 4.2 \times 10^{-4}$

C. $N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$ $K_{eq} = 4.5$

D. $SO_{2(g)} + NO_{2(g)} \rightleftarrows NO_{(g)} + SO_{3(g)}$ $K_{eq} = 85$

13. Consider the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)}$$

What is the final result of adding some NH_3 gas to the system at constant volume? **(1 mark)**

A. K_{eq} increases.

B. $[H_2]$ decreases.

C. $[NH_3]$ decreases.

D. K_{eq} remains unchanged.

14. Consider the following system:

$$2CO_{(g)} + O_{2(g)} \rightleftarrows 2CO_{2(g)}$$

A container is initially filled with CO and O_2. How will the $[CO]$ and $[CO_2]$ change as the system reaches equilibrium? **(2 marks)**

	$[CO]$	$[CO_2]$
A.	increase	decrease
B.	increase	increase
C.	decrease	decrease
D.	decrease	increase

15. Which of the following will dissolve to form a molecular solution? **(1 mark)**

A. H_2SO_4
B. $AgNO_3$
C. $Ca(OH)_2$
D. $C_6H_{12}O_6$

16. Consider the following equilibrium:

$$\text{energy} + AgCl_{(s)} \rightleftarrows Ag^+_{(aq)} + Cl^-_{(aq)}$$

Addition of which of the following will increase the solubility of AgCl ? **(1 mark)**

A. heat
B. HCl
C. $AgNO_3$
D. a catalyst

17. What is the $\left[Cl^-\right]$ when 15.0 g of NaCl is dissolved in enough water to make 100.0 mL of solution? **(1 mark)**

A. 0.150 M
B. 0.390 M
C. 2.56 M
D. 3.90 M

18. An equal number of moles of Na_2CO_3 is added to four different 10.0 mL samples.

Sample 1	Sample 2	Sample 3	Sample 4
0.50 M $Ba^{2+}_{(aq)}$	0.50 M $Ca^{2+}_{(aq)}$	0.50 M $Mg^{2+}_{(aq)}$	0.50 M $Sr^{2+}_{(aq)}$

A precipitate forms in only one of the samples. Identify the cation which is present in the precipitate. **(1 mark)**

A. Ba^{2+}
B. Ca^{2+}
C. Mg^{2+}
D. Sr^{2+}

OVER

19. What is the net ionic equation for the reaction between $BaS_{(aq)}$ and $Sr(OH)_{2(aq)}$? **(1 mark)**

A. $Sr^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow SrS_{(s)}$

B. $Ba^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Ba(OH)_{2(s)}$

C. $Ba^{2+}_{(aq)} + S^{2-}_{(aq)} + Sr^{2+}_{(aq)} + 2\,OH^{-}_{(aq)} \rightarrow Ba(OH)_{2(s)} + SrS_{(s)}$

D. $Ba^{2+}_{(aq)} + S^{2-}_{(aq)} + Sr^{2+}_{(aq)} + 2\,OH^{-}_{(aq)} \rightarrow Ba(OH)_{2(s)} + Sr^{2+}_{(aq)} + S^{2-}_{(aq)}$

20. In which of the following would $PbCl_{2(s)}$ be **least** soluble? **(1 mark)**

A. $1\,M$ HCl

B. $1\,M$ $BaCl_2$

C. $1\,M$ K_2SO_4

D. $1\,M$ $Pb(NO_3)_2$

21. The solubility of $ZnCO_3$ is $6.4 \times 10^{-9}\,M$. What is the value of K_{sp} for $ZnCO_3$? **(1 mark)**

A. 4.1×10^{-17}

B. 6.4×10^{-9}

C. 1.3×10^{-8}

D. 8.0×10^{-5}

22. When equal volumes of $0.20\,M$ $NaOH$ and $0.20\,M$ CaS are mixed together, **(2 marks)**

A. a precipitate forms and the Trial K_{sp} would be less than K_{sp}.

B. no precipitate forms and the Trial K_{sp} would be less than K_{sp}.

C. a precipitate forms and the Trial K_{sp} would be greater than K_{sp}.

D. no precipitate forms and the Trial K_{sp} would be greater than K_{sp}.

23. Which of the following is a property of **all** acidic solutions at $25°C$? **(1 mark)**

A. They have a pH less than 7.0.
B. They have a pH greater than 7.0.
C. They cause phenolphthalein to turn pink.
D. They release hydrogen when placed on copper metal.

24. When a small solid sample is added to a solution of H_2SO_4, a precipitate forms and the solution becomes less acidic. Which of the following substances could have caused these results? **(2 marks)**

A. Na_2SO_4
B. $Sr(OH)_2$
C. $Mg(OH)_2$
D. $Ca(NO_3)_2$

25. Consider the following reaction:

$$HCN + CH_3NH_2 \rightleftarrows CN^- + CH_3NH_3^+$$

Which of the following describes a conjugate acid-base pair in the equilibrium above? **(2 marks)**

	Acid	Base
A.	CN^-	HCN
B.	$CH_3NH_3^+$	CN^-
C.	HCN	$CH_3NH_3^+$
D.	$CH_3NH_3^+$	CH_3NH_2

OVER

26. Which of the following is the weakest base? **(1 mark)**

A. F^-
B. HS^-
C. CN^-
D. IO_3^-

27. Which of the following relationships is used to calculate K_w at 30°C ? **(1 mark)**

A. $K_w = pH + pOH$
B. $pK_w = -\log\left[H_3O^+\right]$
C. $K_w = \left[H_3O^+\right]\left[OH^-\right]$
D. $K_w = \left[H_3O^+\right] + \left[OH^-\right]$

28. What is the pOH of $0.2\,M$ HNO_3 ? **(2 marks)**

A. 5×10^{-14}
B. 0.2
C. 0.7
D. 13.3

29. Which of the following K_a values represents the acid with the strongest conjugate base? **(1 mark)**

A. $K_a = 4.2 \times 10^{-12}$
B. $K_a = 9.5 \times 10^{-9}$
C. $K_a = 2.0 \times 10^{-5}$
D. $K_a = 7.8 \times 10^{-3}$

30. What is the dissociation equation for Na_2CO_3 in water? **(1 mark)**

A. $Na_2CO_{3(s)} \rightarrow Na^{2+}_{(aq)} + CO_3{}^{2-}_{(aq)}$

B. $Na_2CO_{3(s)} \rightarrow 2Na^{+}_{(aq)} + CO_3{}^{2-}_{(aq)}$

C. $CO_3{}^{2-}_{(aq)} + H_2O_{(\ell)} \rightarrow HCO_3{}^{-}_{(aq)} + OH^{-}_{(aq)}$

D. $Na_2CO_{3(s)} + 2H_2O_{(\ell)} \rightarrow 2NaOH_{(aq)} + H_2CO_{3(aq)}$

31. Which of the following solutions has the highest pH ? **(2 marks)**

A. 0.1M HCl

B. 0.1M NaF

C. 0.1M NaHS

D. 0.1M NH_4Cl

32. The indicator phenolphthalein can be described by the following equilibrium equation:

$$\underset{\text{colourless}}{HIn} + H_2O \rightleftarrows H_3O^+ + \underset{\text{pink}}{In^-}$$

HCl is added to a slightly pink sample of this indicator. After equilibrium has been re-established, how do the $[H_3O^+]$ and the colour of the solution **compare with the original equilibrium**? **(2 marks)**

	$[H_3O^+]$	Colour of Solution
A.	decreases	turns more pink
B.	decreases	turns colourless
C.	increases	turns more pink
D.	increases	turns colourless

OVER

33. What is the K_a value for the indicator neutral red? **(1 mark)**

A. 1×10^{-14}
B. 4×10^{-8}
C. 7.4
D. 14.0

34. Which of the following is **not** a good use for an acid-base titration curve? **(1 mark)**

A. to determine the concentration of the base
B. to select a suitable indicator for the titration
C. to determine whether the acid is strong or weak
D. to select a suitable primary standard for the titration

35. What volume of 0.100 M H_2SO_4 is needed to titrate 25.0 mL of 0.200 M NaOH ? **(2 marks)**

A. 12.5 mL
B. 25.0 mL
C. 50.0 mL
D. 100.0 mL

36. Which of the following pairs of chemicals could be used to make a buffer solution? **(1 mark)**

A. NH_3 and H_2O
B. HCl and NaCl
C. NH_3 and NH_4Cl
D. CH_3COOH and HCl

37. What reaction occurs when sodium oxide dissolves in water? **(1 mark)**

A. $NaO_{(s)} \rightarrow Na^{2+}_{(aq)} + O^{2-}_{(aq)}$

B. $Na_2O_{(s)} \rightarrow Na_2{}^{+}_{(aq)} + O^{2-}_{(aq)}$

C. $NaO_{(s)} + H_2O_{(\ell)} \rightarrow NaOH_{(aq)}$

D. $Na_2O_{(s)} + H_2O_{(\ell)} \rightarrow 2NaOH_{(aq)}$

38. Which equation represents a redox reaction? **(1 mark)**

A. $C + O_2 \rightarrow CO_2$

B. $NH_3 + HCl \rightarrow NH_4Cl$

C. $2CrO_4{}^{2-} + 2H^+ \rightarrow Cr_2O_7{}^{2-} + H_2O$

D. $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

39. What is a typical characteristic of a strong oxidizing agent? **(1 mark)**

A. It is readily oxidized.
B. It easily loses electrons.
C. It has a negative oxidation number.
D. It has a positive reduction potential.

40. When U_3O_8 (pitchblende) is dissolved in nitric acid, it changes into $UO_2(NO_3)_2$ (uranyl nitrate). What is the change in oxidation number for uranium? **(1 mark)**

A. $+2\frac{2}{3}$

B. $+\frac{2}{3}$

C. $-3\frac{1}{3}$

D. -10

OVER

41. The metals Hg, Cd, Ga and Pd react as follows:

$$3Pd^{2+} + 2Ga \rightarrow 2Ga^{3+} + 3Pd$$

$$Cd + Ga^{3+} \rightarrow \text{no reaction}$$

$$Hg^{2+} + Pd \rightarrow Pd^{2+} + Hg$$

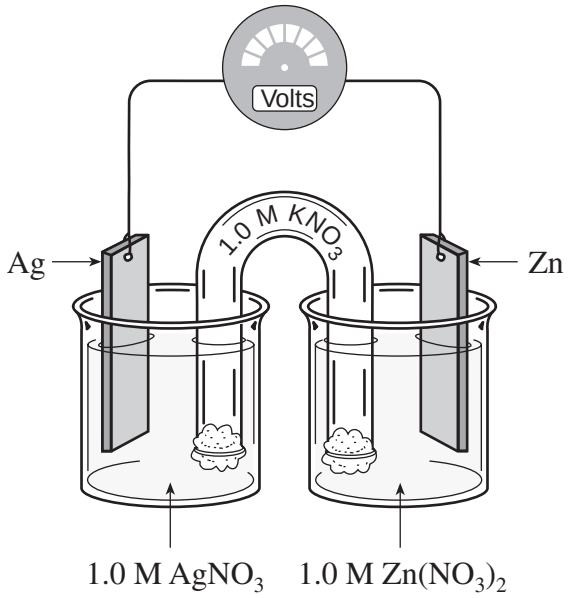
Which of the following metals is the strongest reducing agent? **(2 marks)**

A. Pd
B. Ga
C. Cd
D. Hg

42. Which of the following metals can be oxidized by 1.0 M Fe^{2+} ? **(1 mark)**

A. Sn
B. Co
C. Cr
D. Ag

Use the following diagram to answer questions 43 to 45.



43. What is the equation for the half-reaction that occurs at the cathode? **(1 mark)**

A. $Ag \rightarrow Ag^+ + e^-$

B. $Ag^+ + e^- \rightarrow Ag$

C. $Zn \rightarrow Zn^{2+} + 2e^-$

D. $Zn^{2+} + 2e^- \rightarrow Zn$

44. What happens to the mass of each electrode as the cell operates? **(1 mark)**

A. $Ag_{(s)}$ increases, $Zn_{(s)}$ increases

B. $Ag_{(s)}$ decreases, $Zn_{(s)}$ decreases

C. $Ag_{(s)}$ decreases, $Zn_{(s)}$ increases

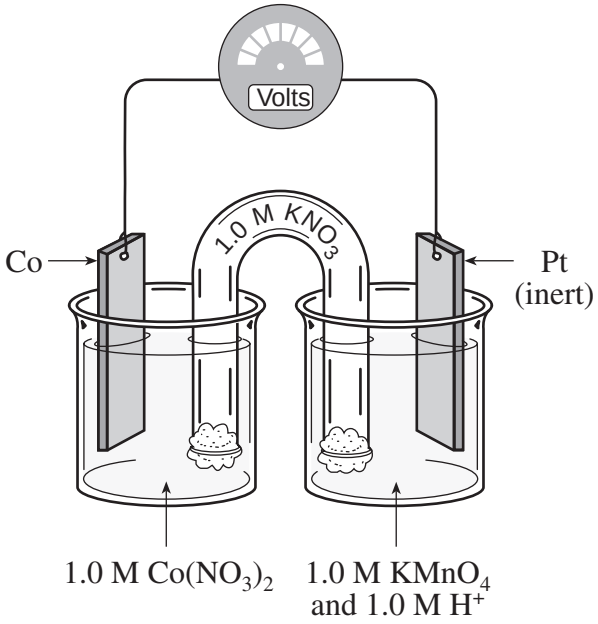
D. $Ag_{(s)}$ increases, $Zn_{(s)}$ decreases

45. Which of the following is correct? **(1 mark)**

	Electrons Flow Towards	Anions Move Towards
A.	Zn	Zn
B.	Zn	Ag
C.	Ag	Zn
D.	Ag	Ag

OVER

46. Consider the following diagram:



Identify the anode reaction for the cell shown in the diagram. **(1 mark)**

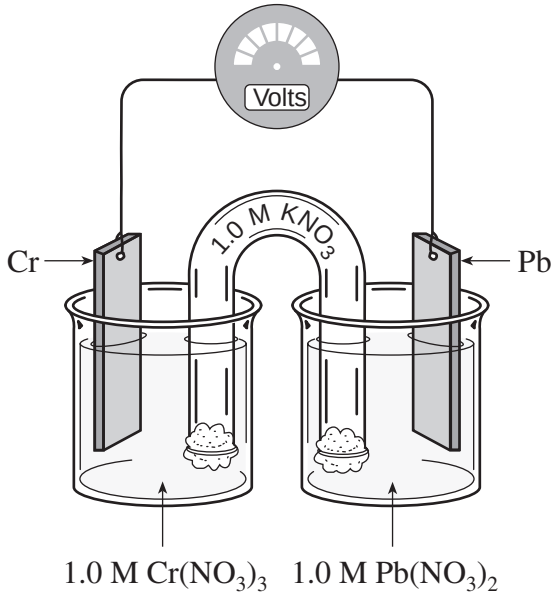
A. $H_2 \rightarrow 2H^+ + 2e^-$

B. $Co \rightarrow Co^{2+} + 2e^-$

C. $Co^{2+} + 2e^- \rightarrow Co$

D. $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

47. Consider the following cell:



What is the initial cell voltage? **(1 mark)**

A. +0.87 V
B. +0.61 V
C. +0.54 V
D. +0.28 V

48. Which of the following are produced at the anode and the cathode in the electrolysis of molten lithium chloride using platinum inert electrodes? **(1 mark)**

	Anode	Cathode
A.	oxygen	hydrogen
B.	hydrogen	oxygen
C.	chlorine	lithium
D.	lithium	chlorine

This is the end of the multiple-choice section.
Answer the remaining questions directly in this examination booklet.

OVER

PART B: WRITTEN RESPONSE

Value: 40 marks **Suggested Time: 50 minutes**

INSTRUCTIONS:	You are expected to communicate your knowledge and understanding of chemical principles in a clear and logical manner. Your steps and assumptions leading to a solution must be written in the spaces below the questions. Answers must include units where appropriate and be given to the correct number of significant figures. **For questions involving calculations, full marks will NOT be given for providing only an answer.**

1. Consider the following reaction: **(3 marks)**

$$Mg_{(s)} + 2HBr_{(aq)} \rightarrow MgBr_{2(aq)} + H_{2(g)} + \text{energy}$$

In terms of collision theory, describe how each of the factors below would influence the reaction rate.

a) Increasing the concentration of HBr: _____

_____

b) Decreasing the temperature: _____

_____

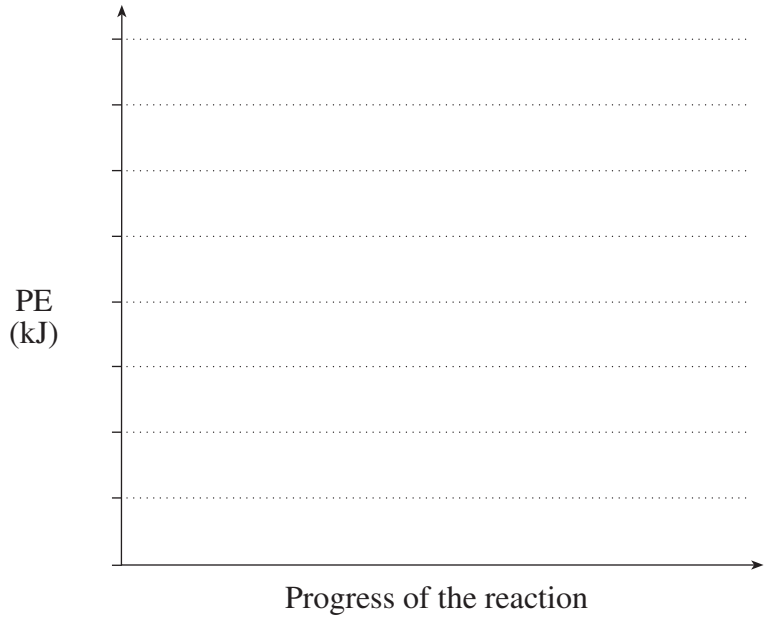
c) Increasing the surface area of Mg: _____

_____

2. Consider the following reaction mechanism: **(2 marks)**

Step 1	$NO_{(g)} + O_{2(g)} \rightarrow NO_{3(g)}$ slow
Step 2	$NO_{3(g)} + NO_{(g)} \rightarrow 2NO_{2(g)}$

The overall reaction is exothermic. Sketch a PE diagram on the axes below to describe the energy changes that occur as the reaction takes place.



3. Consider the following equilibrium system: **(3 marks)**

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

The system is said to "shift right" as the result of the addition of **extra** $H_{2(g)}$. Describe the sequence of changes in both forward and reverse reaction rates as the system goes from the original equilibrium to the new equilibrium.

_____

_____

_____

_____

_____

_____

OVER

4. Consider the following equilibrium system: **(3 marks)**

$$2NO_{(g)} + Cl_{2(g)} \rightleftarrows 2NOCl_{(g)} \qquad K_{eq} = 8.5$$

A closed flask is found to contain $0.40\,M\ NO_{(g)}$, $0.32\,M\ Cl_{2(g)}$ and $5.6\,M\ NOCl_{(g)}$. Use appropriate calculations to determine the direction the reaction proceeds to reach equilibrium.

5. Calculate the maximum mass of $BaCl_{2(s)}$ that can be added to $250\,mL$ of $0.50\,M\ Pb(NO_3)_{2(aq)}$ without forming a precipitate of $PbCl_{2(s)}$. **(6 marks)**

6. Write the net ionic equation for the acid-base reaction that occurs between $NaCN_{(aq)}$ and $NH_4Cl_{(aq)}$. **(2 marks)**

7. Define the term *amphiprotic* and give an example of an amphiprotic anion. **(2 marks)**

_____

_____

_____

8. At $20°C$, the ionization constant of water (K_w) is 6.76×10^{-15}.
Calculate the $[H_3O^+]$ of water at $20°C$. **(2 marks)**

OVER

9. Calculate the pH of 0.50 M NaF. **(5 marks)**

10. Outline a procedure to prepare a buffer solution. **(3 marks)**

_____

_____

_____

_____

11. A reaction occurs when copper metal is dropped into a solution of silver nitrate. Write the balanced formula equation and the balanced net ionic equation for this reaction. **(3 marks)**

Formula equation: _____

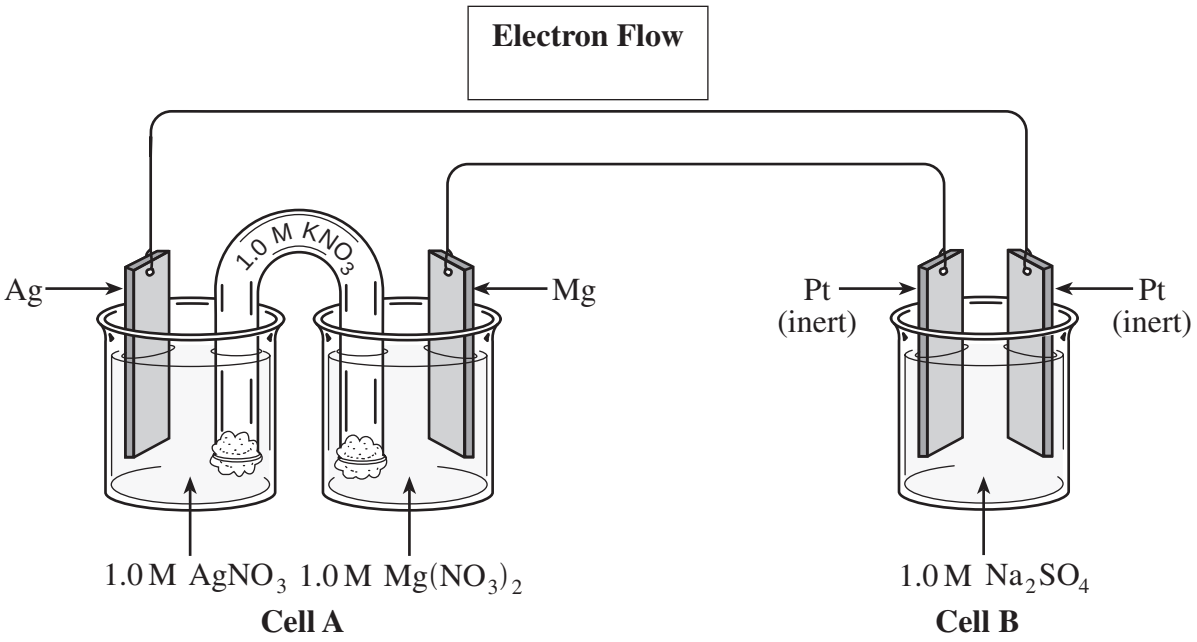
Net ionic equation: _____

12. When setting up the apparatus to electroplate a zinc object with copper, the object is suspended in a Cu^{2+} solution. Explain why it is a good idea to turn on the power supply before immersing the electrodes in the solution. **(1 mark)**

_____

_____

13. Consider the following apparatus consisting of an electrochemical cell joined to an electrolytic cell:



a) On the diagram above, indicate the direction of electron flow in the top wire. **(1 mark)**

b) Which metal in cell A is the cathode? **(1 mark)**

Cathode: _____

c) Write the anode and cathode half-reactions for cell B. **(3 marks)**

Anode: _____

Cathode: _____

END OF EXAMINATION

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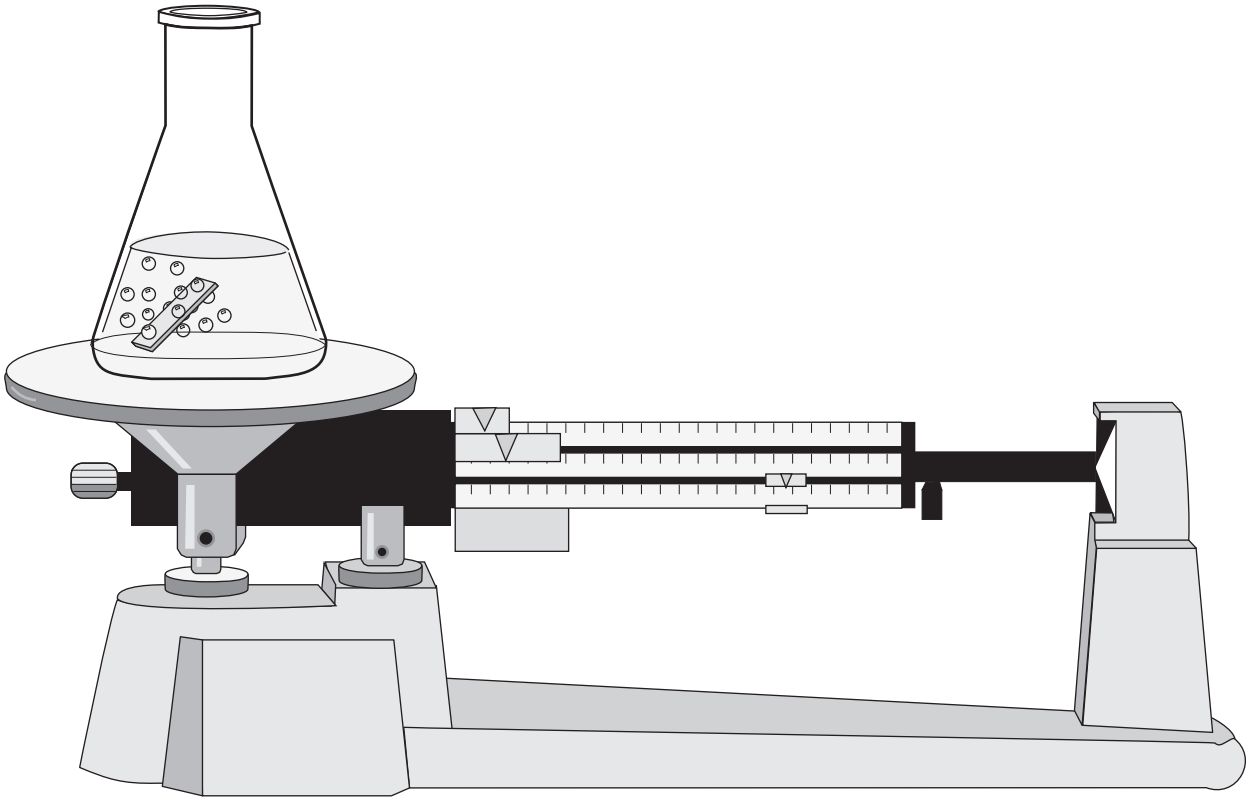
Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



Revised January 2000

CONTENTS

REFERENCE

D.R. Lide, *CRC Handbook of Chemistry and Physics*, 80th edition, CRC Press, Boca Raton, 1999.

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

14 — Atomic Number
Si — Symbol
Silicon — Name
28.1 — Atomic Mass

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce Cerium 140.1	**Pr** Praseodymium 140.9	**Nd** Neodymium 144.2	**Pm** Promethium (145)	**Sm** Samarium 150.4	**Eu** Europium 152.0	**Gd** Gadolinium 157.3	**Tb** Terbium 158.9	**Dy** Dysprosium 162.5	**Ho** Holmium 164.9	**Er** Erbium 167.3	**Tm** Thulium 168.9	**Yb** Ytterbium 173.0	**Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Based on mass of C^{12} at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.

ATOMIC MASSES OF THE ELEMENTS

Based on mass of C^{12} at 12.00.
Values in parentheses are the mass number of the most stable or best known isotopes for elements that do not occur naturally.

Element	Symbol	Atomic Number	Atomic Mass
Actinium	Ac	89	(227)
Aluminum	Al	13	27.0
Americium	Am	95	(243)
Antimony	Sb	51	121.8
Argon	Ar	18	39.9
Arsenic	As	33	74.9
Astatine	At	85	(210)
Barium	Ba	56	137.3
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.0
Bismuth	Bi	83	209.0
Boron	B	5	10.8
Bromine	Br	35	79.9
Cadmium	Cd	48	112.4
Calcium	Ca	20	40.1
Californium	Cf	98	(251)
Carbon	C	6	12.0
Cerium	Ce	58	140.1
Cesium	Cs	55	132.9
Chlorine	Cl	17	35.5
Chromium	Cr	24	52.0
Cobalt	Co	27	58.9
Copper	Cu	29	63.5
Curium	Cm	96	(247)
Dubnium	Db	105	(262)
Dysprosium	Dy	66	162.5
Einsteinium	Es	99	(252)
Erbium	Er	68	167.3
Europium	Eu	63	152.0
Fermium	Fm	100	(257)
Fluorine	F	9	19.0
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.3
Gallium	Ga	31	69.7
Germanium	Ge	32	72.6
Gold	Au	79	197.0
Hafnium	Hf	72	178.5
Helium	He	2	4.0
Holmium	Ho	67	164.9
Hydrogen	H	1	1.0
Indium	In	49	114.8
Iodine	I	53	126.9
Iridium	Ir	77	192.2
Iron	Fe	26	55.8
Krypton	Kr	36	83.8
Lanthanum	La	57	138.9
Lawrencium	Lr	103	(262)
Lead	Pb	82	207.2
Lithium	Li	3	6.9
Lutetium	Lu	71	175.0
Magnesium	Mg	12	24.3
Manganese	Mn	25	54.9
Mendelevium	Md	101	(258)
Mercury	Hg	80	200.6
Molybdenum	Mo	42	95.9
Neodymium	Nd	60	144.2
Neon	Ne	10	20.2
Neptunium	Np	93	(237)
Nickel	Ni	28	58.7
Niobium	Nb	41	92.9
Nitrogen	N	7	14.0
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	O	8	16.0
Palladium	Pd	46	106.4
Phosphorus	P	15	31.0
Platinum	Pt	78	195.1
Plutonium	Pu	94	(244)
Polonium	Po	84	(209)
Potassium	K	19	39.1
Praseodymium	Pr	59	140.9
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.0
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.9
Rubidium	Rb	37	85.5
Ruthenium	Ru	44	101.1
Rutherfordium	Rf	104	(261)
Samarium	Sm	62	150.4
Scandium	Sc	21	45.0
Selenium	Se	34	79.0
Silicon	Si	14	28.1
Silver	Ag	47	107.9
Sodium	Na	11	23.0
Strontium	Sr	38	87.6
Sulphur	S	16	32.1
Tantalum	Ta	73	180.9
Technetium	Tc	43	(98)
Tellurium	Te	52	127.6
Terbium	Tb	65	158.9
Thallium	Tl	81	204.4
Thorium	Th	90	232.0
Thulium	Tm	69	168.9
Tin	Sn	50	118.7
Titanium	Ti	22	47.9
Tungsten	W	74	183.8
Uranium	U	92	238.0
Vanadium	V	23	50.9
Xenon	Xe	54	131.3
Ytterbium	Yb	70	173.0
Yttrium	Y	39	88.9
Zinc	Zn	30	65.4
Zirconium	Zr	40	91.2

NAMES, FORMULAE, AND CHARGES OF SOME COMMON IONS

* *Aqueous solutions are readily oxidized by air.*
** *Not stable in aqueous solutions.*

Positive Ions (Cations)			
Al^{3+}	Aluminum	Pb^{4+}	Lead(IV), plumbic
NH_4^+	Ammonium	Li^+	Lithium
Ba^{2+}	Barium	Mg^{2+}	Magnesium
Ca^{2+}	Calcium	Mn^{2+}	Manganese(II), manganous
Cr^{2+}	Chromium(II), chromous	Mn^{4+}	Manganese(IV)
Cr^{3+}	Chromium(III), chromic	Hg_2^{2+}	Mercury(I)*, mercurous
Cu^+	Copper(I)*, cuprous	Hg^{2+}	Mercury(II), mercuric
Cu^{2+}	Copper(II), cupric	K^+	Potassium
H^+	Hydrogen	Ag^+	Silver
H_3O^+	Hydronium	Na^+	Sodium
Fe^{2+}	Iron(II)*, ferrous	Sn^{2+}	Tin(II)*, stannous
Fe^{3+}	Iron(III), ferric	Sn^{4+}	Tin(IV), stannic
Pb^{2+}	Lead(II), plumbous	Zn^{2+}	Zinc

Negative Ions (Anions)			
Br^-	Bromide	OH^-	Hydroxide
CO_3^{2-}	Carbonate	ClO^-	Hypochlorite
ClO_3^-	Chlorate	I^-	Iodide
Cl^-	Chloride	HPO_4^{2-}	Monohydrogen phosphate
ClO_2^-	Chlorite	NO_3^-	Nitrate
CrO_4^{2-}	Chromate	NO_2^-	Nitrite
CN^-	Cyanide	$C_2O_4^{2-}$	Oxalate
$Cr_2O_7^{2-}$	Dichromate	O^{2-}	Oxide**
$H_2PO_4^-$	Dihydrogen phosphate	ClO_4^-	Perchlorate
CH_3COO^-	Ethanoate, acetate	MnO_4^-	Permanganate
F^-	Fluoride	PO_4^{3-}	Phosphate
HCO_3^-	Hydrogen carbonate, bicarbonate	SO_4^{2-}	Sulphate
$HC_2O_4^-$	Hydrogen oxalate, binoxalate	S^{2-}	Sulphide
HSO_4^-	Hydrogen sulphate, bisulphate	SO_3^{2-}	Sulphite
HS^-	Hydrogen sulphide, bisulphide	SCN^-	Thiocyanate
HSO_3^-	Hydrogen sulphite, bisulphite		

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

SOLUBILITY PRODUCT CONSTANTS AT 25°C

Name	Formula	K_{sp}
Barium carbonate	$BaCO_3$	2.6×10^{-9}
Barium chromate	$BaCrO_4$	1.2×10^{-10}
Barium sulphate	$BaSO_4$	1.1×10^{-10}
Calcium carbonate	$CaCO_3$	5.0×10^{-9}
Calcium oxalate	CaC_2O_4	2.3×10^{-9}
Calcium sulphate	$CaSO_4$	7.1×10^{-5}
Copper(I) iodide	CuI	1.3×10^{-12}
Copper(II) iodate	$Cu(IO_3)_2$	6.9×10^{-8}
Copper(II) sulphide	CuS	6.0×10^{-37}
Iron(II) hydroxide	$Fe(OH)_2$	4.9×10^{-17}
Iron(II) sulphide	FeS	6.0×10^{-19}
Iron(III) hydroxide	$Fe(OH)_3$	2.6×10^{-39}
Lead(II) bromide	$PbBr_2$	6.6×10^{-6}
Lead(II) chloride	$PbCl_2$	1.2×10^{-5}
Lead(II) iodate	$Pb(IO_3)_2$	3.7×10^{-13}
Lead(II) iodide	PbI_2	8.5×10^{-9}
Lead(II) sulphate	$PbSO_4$	1.8×10^{-8}
Magnesium carbonate	$MgCO_3$	6.8×10^{-6}
Magnesium hydroxide	$Mg(OH)_2$	5.6×10^{-12}
Silver bromate	$AgBrO_3$	5.3×10^{-5}
Silver bromide	$AgBr$	5.4×10^{-13}
Silver carbonate	Ag_2CO_3	8.5×10^{-12}
Silver chloride	$AgCl$	1.8×10^{-10}
Silver chromate	Ag_2CrO_4	1.1×10^{-12}
Silver iodate	$AgIO_3$	3.2×10^{-8}
Silver iodide	AgI	8.5×10^{-17}
Strontium carbonate	$SrCO_3$	5.6×10^{-10}
Strontium fluoride	SrF_2	4.3×10^{-9}
Strontium sulphate	$SrSO_4$	3.4×10^{-7}
Zinc sulphide	ZnS	2.0×10^{-25}

RELATIVE STRENGTHS OF BRØNSTED-LOWRY ACIDS AND BASES

in aqueous solution at room temperature.

STRENGTH OF ACID: STRONG (top) → WEAK (bottom)

STRENGTH OF BASE: WEAK (top) → STRONG (bottom)

Name of Acid	Acid		Base	K_a
Perchloric	$HClO_4$	$\rightarrow$	$H^+ + ClO_4^-$	very large
Hydriodic	HI	$\rightarrow$	$H^+ + I^-$	very large
Hydrobromic	HBr	$\rightarrow$	$H^+ + Br^-$	very large
Hydrochloric	HCl	$\rightarrow$	$H^+ + Cl^-$	very large
Nitric	HNO_3	$\rightarrow$	$H^+ + NO_3^-$	very large
Sulphuric	H_2SO_4	$\rightarrow$	$H^+ + HSO_4^-$	very large
Hydronium Ion	H_3O^+	$\rightleftarrows$	$H^+ + H_2O$	1.0
Iodic	HIO_3	$\rightleftarrows$	$H^+ + IO_3^-$	1.7×10^{-1}
Oxalic	$H_2C_2O_4$	$\rightleftarrows$	$H^+ + HC_2O_4^-$	5.9×10^{-2}
Sulphurous $(SO_2 + H_2O)$	H_2SO_3	$\rightleftarrows$	$H^+ + HSO_3^-$	1.5×10^{-2}
Hydrogen sulphate ion	HSO_4^-	$\rightleftarrows$	$H^+ + SO_4^{2-}$	1.2×10^{-2}
Phosphoric	H_3PO_4	$\rightleftarrows$	$H^+ + H_2PO_4^-$	7.5×10^{-3}
Hexaaquoiron ion, iron(III) ion	$Fe(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}
Citric	$H_3C_6H_5O_7$	$\rightleftarrows$	$H^+ + H_2C_6H_5O_7^-$	7.1×10^{-4}
Nitrous	HNO_2	$\rightleftarrows$	$H^+ + NO_2^-$	4.6×10^{-4}
Hydrofluoric	HF	$\rightleftarrows$	$H^+ + F^-$	3.5×10^{-4}
Methanoic, formic	$HCOOH$	$\rightleftarrows$	$H^+ + HCOO^-$	1.8×10^{-4}
Hexaaquochromium ion, chromium(III) ion	$Cr(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Cr(H_2O)_5(OH)^{2+}$	1.5×10^{-4}
Benzoic	C_6H_5COOH	$\rightleftarrows$	$H^+ + C_6H_5COO^-$	6.5×10^{-5}
Hydrogen oxalate ion	$HC_2O_4^-$	$\rightleftarrows$	$H^+ + C_2O_4^{2-}$	6.4×10^{-5}
Ethanoic, acetic	CH_3COOH	$\rightleftarrows$	$H^+ + CH_3COO^-$	1.8×10^{-5}
Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	$\rightleftarrows$	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}
Hexaaquoaluminum ion, aluminum ion	$Al(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Al(H_2O)_5(OH)^{2+}$	1.4×10^{-5}
Carbonic $(CO_2 + H_2O)$	H_2CO_3	$\rightleftarrows$	$H^+ + HCO_3^-$	4.3×10^{-7}
Monohydrogen citrate ion	$HC_6H_5O_7^{2-}$	$\rightleftarrows$	$H^+ + C_6H_5O_7^{3-}$	4.1×10^{-7}
Hydrogen sulphite ion	HSO_3^-	$\rightleftarrows$	$H^+ + SO_3^{2-}$	1.0×10^{-7}
Hydrogen sulphide	H_2S	$\rightleftarrows$	$H^+ + HS^-$	9.1×10^{-8}
Dihydrogen phosphate ion	$H_2PO_4^-$	$\rightleftarrows$	$H^+ + HPO_4^{2-}$	6.2×10^{-8}
Boric	H_3BO_3	$\rightleftarrows$	$H^+ + H_2BO_3^-$	7.3×10^{-10}
Ammonium ion	NH_4^+	$\rightleftarrows$	$H^+ + NH_3$	5.6×10^{-10}
Hydrocyanic	HCN	$\rightleftarrows$	$H^+ + CN^-$	4.9×10^{-10}
Phenol	C_6H_5OH	$\rightleftarrows$	$H^+ + C_6H_5O^-$	1.3×10^{-10}
Hydrogen carbonate ion	HCO_3^-	$\rightleftarrows$	$H^+ + CO_3^{2-}$	5.6×10^{-11}
Hydrogen peroxide	H_2O_2	$\rightleftarrows$	$H^+ + HO_2^-$	2.4×10^{-12}
Monohydrogen phosphate ion	HPO_4^{2-}	$\rightleftarrows$	$H^+ + PO_4^{3-}$	2.2×10^{-13}
Water	H_2O	$\rightleftarrows$	$H^+ + OH^-$	1.0×10^{-14}
Hydroxide ion	OH^-	$\leftarrow$	$H^+ + O^{2-}$	very small
Ammonia	NH_3	$\leftarrow$	$H^+ + NH_2^-$	very small

ACID-BASE INDICATORS

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl violet	0.0 – 1.6	yellow to blue
Thymol blue	1.2 – 2.8	red to yellow
Orange IV	1.4 – 2.8	red to yellow
Methyl orange	3.2 – 4.4	red to yellow
Bromcresol green	3.8 – 5.4	yellow to blue
Methyl red	4.8 – 6.0	red to yellow
Chlorophenol red	5.2 – 6.8	yellow to red
Bromthymol blue	6.0 – 7.6	yellow to blue
Phenol red	6.6 – 8.0	yellow to red
Neutral red	6.8 – 8.0	red to amber
Thymol blue	8.0 – 9.6	yellow to blue
Phenolphthalein	8.2 – 10.0	colourless to pink
Thymolphthalein	9.4 – 10.6	colourless to blue
Alizarin yellow	10.1 – 12.0	yellow to red
Indigo carmine	11.4 – 13.0	blue to yellow

STANDARD REDUCTION POTENTIALS OF HALF-CELLS

Ionic concentrations are at 1M in water at 25°C.

Oxidizing Agents		Reducing Agents	E° (Volts)
$F_{2(g)} + 2e^-$	⇄	$2F^-$	+2.87
$S_2O_8^{2-} + 2e^-$	⇄	$2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^-$	⇄	$2H_2O$	+1.78
$MnO_4^- + 8H^+ + 5e^-$	⇄	$Mn^{2+} + 4H_2O$	+1.51
$Au^{3+} + 3e^-$	⇄	$Au_{(s)}$	+1.50
$BrO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}Br_{2(\ell)} + 3H_2O$	+1.48
$ClO_4^- + 8H^+ + 8e^-$	⇄	$Cl^- + 4H_2O$	+1.39
$Cl_{2(g)} + 2e^-$	⇄	$2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇄	$2Cr^{3+} + 7H_2O$	+1.23
$\frac{1}{2}O_{2(g)} + 2H^+ + 2e^-$	⇄	H_2O	+1.23
$MnO_{2(s)} + 4H^+ + 2e^-$	⇄	$Mn^{2+} + 2H_2O$	+1.22
$IO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}I_{2(s)} + 3H_2O$	+1.20
$Br_{2(\ell)} + 2e^-$	⇄	$2Br^-$	+1.09
$AuCl_4^- + 3e^-$	⇄	$Au_{(s)} + 4Cl^-$	+1.00
$NO_3^- + 4H^+ + 3e^-$	⇄	$NO_{(g)} + 2H_2O$	+0.96
$Hg^{2+} + 2e^-$	⇄	$Hg_{(\ell)}$	+0.85
$\frac{1}{2}O_{2(g)} + 2H^+(10^{-7}\,M) + 2e^-$	⇄	H_2O	+0.82
$2NO_3^- + 4H^+ + 2e^-$	⇄	$N_2O_4 + 2H_2O$	+0.80
$Ag^+ + e^-$	⇄	$Ag_{(s)}$	+0.80
$\frac{1}{2}Hg_2^{2+} + e^-$	⇄	$Hg_{(\ell)}$	+0.80
$Fe^{3+} + e^-$	⇄	Fe^{2+}	+0.77
$O_{2(g)} + 2H^+ + 2e^-$	⇄	H_2O_2	+0.70
$MnO_4^- + 2H_2O + 3e^-$	⇄	$MnO_{2(s)} + 4OH^-$	+0.60
$I_{2(s)} + 2e^-$	⇄	$2I^-$	+0.54
$Cu^+ + e^-$	⇄	$Cu_{(s)}$	+0.52
$H_2SO_3 + 4H^+ + 4e^-$	⇄	$S_{(s)} + 3H_2O$	+0.45
$Cu^{2+} + 2e^-$	⇄	$Cu_{(s)}$	+0.34
$SO_4^{2-} + 4H^+ + 2e^-$	⇄	$H_2SO_3 + H_2O$	+0.17
$Cu^{2+} + e^-$	⇄	Cu^+	+0.15
$Sn^{4+} + 2e^-$	⇄	Sn^{2+}	+0.15
$S_{(s)} + 2H^+ + 2e^-$	⇄	$H_2S_{(g)}$	+0.14
$2H^+ + 2e^-$	⇄	$H_{2(g)}$	+0.00
$Pb^{2+} + 2e^-$	⇄	$Pb_{(s)}$	−0.13
$Sn^{2+} + 2e^-$	⇄	$Sn_{(s)}$	−0.14
$Ni^{2+} + 2e^-$	⇄	$Ni_{(s)}$	−0.26
$H_3PO_4 + 2H^+ + 2e^-$	⇄	$H_3PO_3 + H_2O$	−0.28
$Co^{2+} + 2e^-$	⇄	$Co_{(s)}$	−0.28
$Se_{(s)} + 2H^+ + 2e^-$	⇄	H_2Se	−0.40
$Cr^{3+} + e^-$	⇄	Cr^{2+}	−0.41
$2H_2O + 2e^-$	⇄	$H_2 + 2OH^-(10^{-7}\,M)$	−0.41
$Fe^{2+} + 2e^-$	⇄	$Fe_{(s)}$	−0.45
$Ag_2S_{(s)} + 2e^-$	⇄	$2Ag_{(s)} + S^{2-}$	−0.69
$Cr^{3+} + 3e^-$	⇄	$Cr_{(s)}$	−0.74
$Zn^{2+} + 2e^-$	⇄	$Zn_{(s)}$	−0.76
$Te_{(s)} + 2H^+ + 2e^-$	⇄	H_2Te	−0.79
$2H_2O + 2e^-$	⇄	$H_{2(g)} + 2OH^-$	−0.83
$Mn^{2+} + 2e^-$	⇄	$Mn_{(s)}$	−1.19
$Al^{3+} + 3e^-$	⇄	$Al_{(s)}$	−1.66
$Mg^{2+} + 2e^-$	⇄	$Mg_{(s)}$	−2.37
$Na^+ + e^-$	⇄	$Na_{(s)}$	−2.71
$Ca^{2+} + 2e^-$	⇄	$Ca_{(s)}$	−2.87
$Sr^{2+} + 2e^-$	⇄	$Sr_{(s)}$	−2.89
$Ba^{2+} + 2e^-$	⇄	$Ba_{(s)}$	−2.91
$K^+ + e^-$	⇄	$K_{(s)}$	−2.93
$Rb^+ + e^-$	⇄	$Rb_{(s)}$	−2.98
$Cs^+ + e^-$	⇄	$Cs_{(s)}$	−3.03
$Li^+ + e^-$	⇄	$Li_{(s)}$	−3.04

Overpotential Effect

Overpotential Effect

STRONG

STRENGTH OF OXIDIZING AGENT

WEAK

WEAK

STRENGTH OF REDUCING AGENT

STRONG